

## 6.13 Example M: Longitudinal Discrete Fiber Breakage

### Sample Input File for Longitudinal Discrete Fiber Breakage

Problem Summary

Load Type:	Thermomechanical				
Load History:	Cyclic				
Load Control:	Strain				
Load Component:	11-direction (in fiber direction)				
Load History Data:	<p>Cool-down from 900°C to 23°C, heat-up to 650°C, then hold temperature during mechanical loading</p> $\dot{T} = 0.0152 \text{ } ^\circ\text{C/sec}$ , $0.0871 \text{ } ^\circ\text{C/sec}$ $\dot{\varepsilon} = 1.0 \times 10^{-4}/\text{sec}$ , $\varepsilon_{max} = 0.012$ , $\varepsilon_{min} = 0$ . $\Delta t_{thermal} = 500.$ , 40. sec.; $\Delta t_{mech} = 0.4 \text{ sec.}$				
Micromechanics Model:	Triple Periodicity				
Fiber Packing Arrangement:	Square Pack, 35% fiber volume ratio				
Repeating Unit Cell:	1x8x14 unit cell with 28 square fibers (input manually)				
Integration Algorithm:	Forward Euler				
Constituent Material Model:	<table border="0"> <tr> <td>Fiber:</td> <td>Elastic, transversely isotropic</td> </tr> <tr> <td>Matrix:</td> <td>GVIPS - isotropic form</td> </tr> </table>	Fiber:	Elastic, transversely isotropic	Matrix:	GVIPS - isotropic form
Fiber:	Elastic, transversely isotropic				
Matrix:	GVIPS - isotropic form				
Constituents:	<table border="0"> <tr> <td>Fiber:</td> <td>SCS-6 (temp. dep. properties input manually)</td> </tr> <tr> <td>Matrix:</td> <td>TIMETAL21S</td> </tr> </table>	Fiber:	SCS-6 (temp. dep. properties input manually)	Matrix:	TIMETAL21S
Fiber:	SCS-6 (temp. dep. properties input manually)				
Matrix:	TIMETAL21S				
Fiber Breakage:	Second implementation of debond model				
Fiber Breakage Parameters:	taken from room temperature SCS-6 fiber strength histogram with strengths decreased by 5.8 % to account for elevated temperature effect.				
	$\Lambda = 1.0 \times 10^{-5} \frac{\text{in}^3}{\text{kip}}, \quad B = 10. \frac{1}{\text{s}}$				

☞ **Note:** In the case of longitudinal discrete fiber breakage, each fiber is modeled with an internal weak interface oriented normal to the fiber direction encompassing the entire fiber cross-section. This interface is then given a strength,  $\sigma_{DB}$ , which corresponds to the fiber ultimate strength. Thus, during simulated loading, when the longitudinal stress in the fiber reaches  $\sigma_{DB}$ , the fiber's internal interface debonds, and the longitudinal stress in the fiber begins to unload. This simulates a local fiber failure in a real composite.

In order to model longitudinal discrete fiber breakage as realistically as possible, a subcell containing 28 fibers has been used. Square-shaped fibers have been employed because longitudinal behavior is insensitive to fiber shape, and square fibers require the smallest number of subcells. Strength data for the SCS-6 fiber was taken from a vendor-supplied histogram. The room-temperature simulated distribution, as well as the actual strength distribution are shown in the subsequent figure. Note that the strengths employed in the example (in which the tensile simulation is performed at 650°C) were reduced by 5.8 % from the room-temperature values to account for the effect of the elevated temperature. In addition, the fiber strengths have been distributed over the strength ranges indicated by the histogram, rather than bunched up. That is, rather than providing 5 fibers with a strength of 600 ksi, the strengths of those 5 fibers were distributed between 575 ksi and 625 ksi (prior to the 5.8 % reduction).

The results of this example shown in the subsequent figure have been plotted only to an applied strain level of 0.0096 because at this point the slope of the predicted global stress-strain curve becomes negative. We are treating this as a criterion for simulated global failure of the composite.

test of longitudinal discrete fiber breakage

\*PRINT  
NPL=1 %

\*LOAD  
LCON=3 LOP=1 LSS=1 %

\*MECH  
NPTW=5 TI=0.,24000.,57600.,64800.,64920. LO=0.0,0.0,0.,0.,0.012 %

\*THERM  
NPTT=5 TI=0.,24000.,57600.,64800.,64920. TE=900.,534.583,23.,650.,650. %

\*MODEL  
MOD=2 %

\*SOLVER  
NTF=1 NPTS=5 TIM=0.,24000.,57600.,64800.,64920. STP=500.,40.,40.,0.4 %

\*FIBER  
NFIBS=1  
NF=1 MF=6 NDPT=2 MAT=U IFM=1  
NTP=6  
TEM=21.1,204.44,315.56,426.67,537.78,871.11  
EA=57.0E3,55.98E3,55.4E3,54.82E3,54.24E3,53.36E3  
ET=57.0E3,55.98E3,55.4E3,54.82E3,54.24E3,53.36E3  
NUA=0.25,0.25,0.25,0.25,0.25  
NUT=0.25,0.25,0.25,0.25,0.25  
GA=22.8E3,22.392E3,22.16E3,21.928E3,21.696E3,21.344E3  
ALPA=3.564E-6,3.618E-6,3.726E-6,3.906E-6,4.068E-6,4.572E-6  
ALPT=3.564E-6,3.618E-6,3.726E-6,3.906E-6,4.068E-6,4.572E-6

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NM=1 MM=4 NDPT=2 MAT=A %

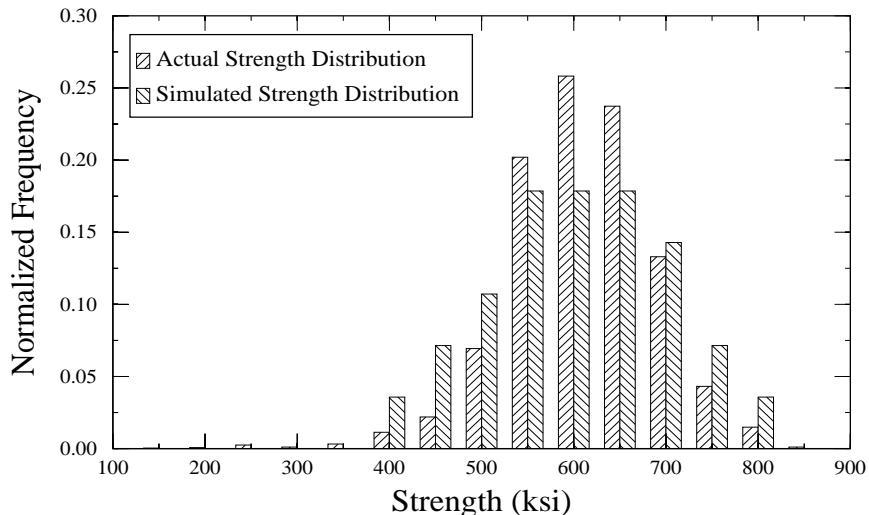
\*MRVE  
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NA=1 NB=8 NG=14  
D=1.0

#NOTE: VF = 35%

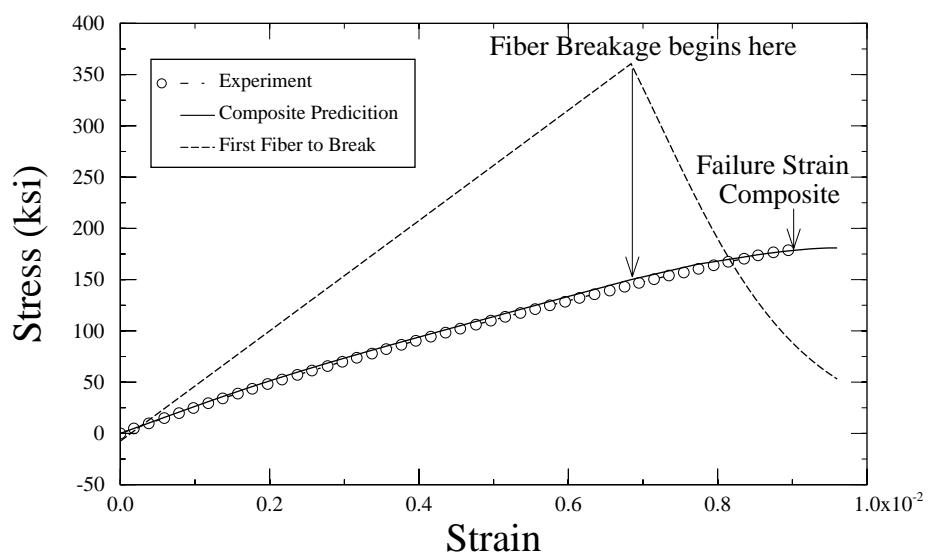
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L=0.5916,0.4084,0.5916,0.4084,0.5916,0.4084,0.5916,0.4084 &  
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CM=M1,M1,M1,M1,M1,M1,M1,M1  
CM=F1,M1,F1,M1,F1,M1,F1,M1  
CM=M1,M1,M1,M1,M1,M1,M1,M1  
CM=F1,M1,F1,M1,F1,M1,F1,M1  
CM=M1,M1,M1,M1,M1,M1,M1,M1  
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CM=F1,M1,F1,M1,F1,M1,F1,M1  
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 CM=F1,M1,F1,M1,F1,M1,F1,M1  
 CM=M1,M1,M1,M1,M1,M1,M1,M1  
 \*DEBOND  
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 BDS=100 GCS=0.1 BCS=100 TI=0  
 DBCH=2 NAI=1 NBI=5 NGI=9 FACE=1 BDN=678 GCN=0.00001 BCN=10. TOLN=1 &  
 BDS=100 GCS=0.1 BCS=100 TI=0  
 DBCH=2 NAI=1 NBI=5 NGI=11 FACE=1 BDN=584 GCN=0.00001 BCN=10. TOLN=1 &  
 BDS=100 GCS=0.1 BCS=100 TI=0  
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 BDS=100 GCS=0.1 BCS=100 TI=0  
 DBCH=2 NAI=1 NBI=7 NGI=1 FACE=1 BDN=575 GCN=0.00001 BCN=10. TOLN=1 &

BDS=100 GCS=0.1 BCS=100 TI=0  
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BDS=100 GCS=0.1 BCS=100 TI=0  
**\*CURVE**  
NP=3 %  
**\*MACRO**  
NT=2  
NC=1 X=1 Y=7 NAM=LONG-M  
NC=2 X=39 Y=1 NAM=LONG-T  
**\*MICRO**  
NT=3  
NC=1 CELL=1 X=1 Y=7 NAM=LONG-1  
NC=2 CELL=17 X=1 Y=7 NAM=LONG-2  
NC=3 CELL=33 X=1 Y=7 NAM=LONG-3 %  
**\*END**



Room Temperature SCS-6 Fiber Strength Histogram



Longitudinal Prediction of SCS-6/Timetal 21S with 35% fiber volume content at 650°C